

ECONOMIC APPENDIX

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SECTION I - INTRODUCTION

General. This appendix presents an economic evaluation of the improvements being considered for the Lafitte study area, which is located in Jefferson Parish, Louisiana. It was prepared in accordance with Engineering Regulation (ER) 1105-2-100, Planning Guidance. The National Economic Development Procedures Manual for Urban Flood Damage, prepared by the Water Resources Support Center, Institute for Water Resources, was used as a reference.

The evaluation consists of a description of the methodology used to determine economic damages and benefits under existing conditions, project costs, and benefit-to-cost analysis. The evaluation uses November 1997 price levels. The proposed improvements (see Plan Formulation) were evaluated by comparing estimated average annual benefits that would accrue to the study area with estimated average annual project costs. Benefits were converted to average annual values by using a Federal discount rate of 7-1/8 percent and a project life of 50 years. The estimated project base year (the year in which significant benefits will accrue as a result of project construction) is the year 2002.

National Economic Development Benefits Considered. The National Economic Development Procedures Manual for Urban Flood Damage recognizes four (4) primary categories of benefits for urban flood control plans: inundation reduction, intensification, location and employment benefits. Inundation reduction is the only category of NED benefits for urban areas considered in this analysis. In addition to the reduction in damages caused by inundation, this category also includes the reduction of emergency costs, evacuation and subsistence costs, reoccupation costs, and Federal Insurance Administration costs saved. The evaluation process involved the formulation and assessment of the flood control improvements, the identification of categories of possible flood control benefits, the determination of without- and with-project damages and costs incurred, and standard benefit-cost comparisons.

The basic economic evaluation included the comparison of the urban flood damage setting for “without-project” and “with-project” conditions. Without-project conditions, or existing conditions, reflect conditions expected to prevail in the absence of any alternative plan of improvement. With-project conditions reflect conditions in the project area with a proposed flood control improvement in place.

Inundation Reduction Benefits. Based on EC 1105-2-100, inundation reduction benefits are associated with physical damages or losses, income losses, and emergency costs. Most activities affected by a flood incur losses in one or more of these categories, but

usually the majority of the benefits from a project result from the reduction of actual or potential physical damages due to inundation. Since income losses are difficult to quantify as a NED benefit because they can be compensated for by a postponement or transfer of activities to other establishments within the nation, they were not included in this analysis.

However, there are viable benefits associated with cost reduction savings from flood emergency operations. These include emergency costs, evacuation and subsistence costs, and reoccupation costs saved. Although physical flood damage reduction and emergency cost reduction are both classified as inundation reduction benefits, they are discussed separately in the following paragraphs.

SECTION II - DESCRIPTION OF THE STUDY AREA

Population and Land Use. The town of Jean Lafitte Louisiana (population 1,500) is located in Jefferson Parish, it is one of eight parishes making up the New Orleans Metropolitan Statistical Area (MSA). The town is located on the West Bank of the Mississippi River, and south of the "Urbanized Area" of the New Orleans MSA, as defined by the 1990 census. Table 1 compares population estimates for the town of Jean Lafitte with the total population of Jefferson Parish and the New Orleans MSA from 1970 to 1993. Jean Lafitte was incorporated, and portions of it annexed, between 1970 and 1980.

Note that the population of Jean Lafitte increased from 936 to 1,496 between 1980 and 1990 while the total population of both Jefferson Parish and the New Orleans metro area slightly declined. The population increase in Jean Lafitte may be characteristic of trends in other communities developed in part by the lower cost of single-family housing and other properties, the appeal of lower population densities, the new construction of or improvements to rapid transportation systems, and higher crime rates in other parts of the metro area. Construction of an additional Mississippi River bridge near the New Orleans central business district could enhance residential developments in Jean Lafitte.

Preliminary surveys of estimated damage to residential property from recent flood and hurricane events, and the number of people living in an average household, indicate that approximately 822 of the 1,500 residents in Jean Lafitte have experienced losses from these events. This estimate is based on the general pattern of single-family dwelling units in the community, the total number (275) of residential structures and mobile homes impacted by recent events, and the 1990 census estimate of the size of an average household in the town of Jean Lafitte (275×2.99 persons/ household = 822 persons). As noted by the Bureau of the Census, a large number of people in the United States were not

included in the 1990 census count for various reasons. The data shown in the table include only the information reported by the census.

In spite of frequent storms making up part of the semi-tropical climate of the area, the unusually low elevation of the delta, the mild climate, and the availability of abundant natural resources combine to promote economic development and population growth along the Louisiana Gulf Coast, the New Orleans metropolitan area, and the town of Jean Lafitte.

Since the population of Jean Lafitte is relatively small, the availability of published data on land use and other socio-economic conditions is limited. The 1990 census reported that the political boundaries of Jean Lafitte covered approximately 6.3 square miles, including 6.0 square miles of land area. Surveys conducted in conjunction with a preliminary phase of this study estimated that 271 residential structures experienced damage during recent hurricane and flooding events, including damage from Hurricane Juan in 1985. As previously mentioned, most of the residential structures in the town of Jean Lafitte are single-family units. In addition to the 275 residential structures, 34 commercial establishments experienced hurricane and flood damage.

The total land area in Jean Lafitte represents only about 2 percent of the total land area in Jefferson Parish. The 1990 census indicates that the political boundaries of Jefferson Parish, both East and West Banks of the Mississippi River, cover approximately 642.4 square miles, including 305.9 square miles of land and another 336.5 square miles of water. A 1980 summary of total land use for the parish prepared by the Louisiana Office of State Planning estimated the total land area of the parish at about 319.57 square miles. This preliminary estimate showed that 72 percent of the total land area in Jefferson Parish was wetland and beaches. About 15 percent was residential land (including a significant amount of the urbanized portion of the New Orleans metropolitan area); another 7 percent was commercial and industrial land; 4 percent was used for transportation, communication, and related services; and the remaining 2 percent was either agricultural land, forest land, strip mines and quarries, sandy areas other than beaches, and land in transition.

Table 1
Population Trends in the Town of Jean Lafitte
Jefferson Parish, and the New Orleans MSA

AREA	1970	1980	1990	1993/a
Jean Lafitte	539	936/b	1,469	1,519
Jefferson Parish	338,229	454,592	448,306	457,069
New Orleans MSA/c	1,144,791	1,304,212	1,286,270	1,306,546

a/ Louisiana Tech University, Business and Administration Research Division, unpublished 1994.

b/ The Town of Jean Lafitte was incorporated prior to the 1990 census. (See footnote 24, 1980 Census of Population, "Number of Inhabitants, Louisiana").

c/ Metropolitan Statistical Area, which currently includes Jefferson, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St. John the Baptist, and St. Tammany Parishes.

SOURCES: U.S. Department of Commerce, Bureau of the Census, Census of Population for 1870 and 1980, "Number of Inhabitants, Louisiana"; and 1990 Census of Population and Housing, "Population and Housing Unit Counts, Louisiana". See also items a/ and b/ above.

Businesses and Employment. The businesses and related employment within the incorporated limits of Jean Lafitte include the markets and services traditionally required to maintain a small suburban community in close proximity to a much larger urban center. Businesses include such things as retail stores selling food, clothing, medical supplies, home furnishings, automobiles, trucks, and boats; and various service establishments providing health care, sanitation, legal services, and automobile and boat maintenance. Other business activities more unique to the local area include the operation and maintenance of the commercial fishing vessels docked along the bayou and activities in support of oil and gas production.

The much larger population of Jefferson Parish requires a much greater level of business activity. In addition to the types of business mentioned above, Jefferson Parish offers jobs

associated with the Port of New Orleans, related industrial activity along the Mississippi River, petro-chemical industries, tourism, in a much larger volume and variety of markets.

Table 2 compares employment, unemployment, and unemployment rates, and the median family income in Jean Lafitte and Jefferson Parish. The 1990 census appears to be the first published information providing employment and median family income data for communities with populations of less than 2,500. The median family income estimates shown in the table are from the 1980 and 1990 census. They have not been adjusted to reflect the unusual pattern of inflation, which occurred nationally between 1979 and 1989.

The 1980 census indicated that Jefferson Parish ranked first among all Louisiana parishes in median family income. The 1990 census reported that the \$32,446 median family income in Jefferson Parish was still among the highest in the State. It ranked slightly behind two other parishes in the New Orleans MSA, St. Charles Parish with \$35,355 and St. Tammany Parishes with \$35,033. The only other parish in the State with median family income higher than that of Jefferson was East Baton Rouge Parish with \$34,198.

Table 2
1990 Civilian Labor Force, Employment, and Unemployment
And Income in Jean Lafitte LA and Jefferson Parish

AREA	1980/a	1990/b	1994/c (April)
Jean Lafitte:			
Civilian Labor Force	*	571	*
Employed	*	531	*
Unemployed	*	40	*
Unemployment Rate	*	7.0	*
Median Family Income	*	\$22,125	*
Jefferson Parish:			
Civilian Labor Force	214,909	222,939	226,700
Employed	205,987	207,556	212,600
Unemployed	8,922	15,383	14,100
Unemployment Rate	4.2	6.9	6.2
Median Family Income	\$21,920	\$32,446	*

* Not available

a/ U.S. Department of Commerce, Bureau of the Census, 1980 Census of Population, "General Social and Economic Characteristics, Louisiana". Income data are for the entire previous (1979) year, and unadjusted for changing price levels.

b/ U.S. Department of Commerce, Bureau of the Census, 1990 Census of Population and Housing, "Summary Social, Economic, and Housing Characteristics, Louisiana". Income data are for the entire previous (1989) year and unadjusted for changing price levels.

c/ Louisiana, Department of Labor, unpublished data.

SECTION III – INUNDATION REDUCTION BENEFITS FOR STRUCTURES AND AUTOMOBILES

Flood Damage Reduction. Most of the benefits that accrue from a project are usually the result of reducing physical flood damages. Physical inundation reduction damages include structural damages to buildings and losses to contents; damages to roads, bridges, and other public utilities; and losses to personal property such as automobiles. In determining potential flood damages for this area, flood damages were evaluated for urban structures and automobiles.

Analysis of Flood Damages to Structures. In the initiation of urban flood damage analyses, field investigations were conducted and data were collected to identify the extent and character of flooding in the project area. The determination of existing urban flood damages was based on the integration of depth-damage relationships and flood frequency distributions to structures located in the area. Development of the existing structure data was based upon a comprehensive field survey of all the structures located within the alignment of the project area. Applicable flood damage curves were used to depict the relationships between the stage and area inundated, stage and frequency of occurrence, stage and damage, and damage and frequency of occurrence. These curves are the basis for the damage/benefit analysis in evaluating project alternatives.

Structure Inventory and Valuation. The study area surveyed was the area known as the Fisher School Basin located in the town of Jean Lafitte. A comprehensive field survey (100% inventory of all of the structures within the alignment) was conducted to identify every structure at risk in the study area. The survey estimated the number, value, and elevation of all structures. Ground elevations were determined using 1-foot contours shown on GIS maps provided by a contractor for Jefferson Parish. First floor elevations were estimated using a hand level to insure accuracy.

Structures were surveyed for pertinent characteristics. These included the type of structure and/or business, number of stories, type of foundation and construction, structure dimensions, physical condition of the structure, and the location. Structures were differentiated by 11 basic types -- residential one-story, residential two-story, mobile home, apartment or duplex, professional, retail and personal, warehouses and contractor services, public and semi-public, eating and recreation, groceries and gas stations, and repairs and home use.

Structure and Contents Valuation. Structure and contents values are major elements influencing the impact of depth-damage relationships and magnitude of flood damages to urban structures. For the purposes of estimating urban flood damages, a structure is defined as a building and any attached components, such as built-in appliances, shelves, carpeting, etc. The value of land is excluded in the determination of urban structure values. Contents represent furnishings and equipment, or all items within the structure that are not permanently attached.

Residential structure values were calculated using the Marshall and Swift Residential Estimator Program. This continuously price-adjusted computer program uses cost per square foot, geographically localized by zip code, to calculate a depreciated replacement value for each structure. Mobile homes within the area were assessed using an average value per structure based on size.

In the determination of nonresidential structure values, the Marshall and Swift Commercial Estimator Program was used. This program determines a cost per square foot based on a number of factors, including occupancy of the structure. Marshall and Swift considers over 100 occupancy categories. Buildings are classified by construction type in order to determine a base cost per square foot. The base cost is then adjusted for factors such as heating and cooling, local construction cost, current cost conditions, and age and life expectancy of the building. The value per square foot was multiplied by the square footage size of the building to determine a total value for each nonresidential structure. For depth-damage purposes, occupancy codes were aggregated into eight established categories of nonresidential use.

A summary of the major structure types by average structure value is depicted in Table 3. The data collected on all of the inventoried structures was manually transferred to structure files using the Urban Damage computer program. A summary of the inventory, grouped according to reach and structure type, is displayed in table 3.

Table 3

Structure Inventory

Category of <u>Structures</u>	Number of <u>Structures</u>	Value of <u>Structures</u>	Average <u>Value</u>
Residential (1-sty)	168	\$ 6,762,700	\$ 40,300
Residential (2-sty)	18	905,500	50,300
Mobile Homes	89	612,000	6,900
Commercial	34	3,763,500	110,700

Depth-Damage Relationships. To quantify the extent of flooding, which occurs in an area, depth-damage curves are utilized. Depth-damage relationships and contents to structure value ratios developed by a panel of experts as part of the Jefferson/Orleans Parish Feasibility Studies were used in this analysis. These curves were based on detailed damage surveys of selected residential and nonresidential properties in Jefferson and Orleans Parishes in the State of Louisiana. Each unit was visually inspected with estimated expected damages recorded at various levels of inundation. Structure types, structure value, and type of flooding differentiated these curves. Since the range of structure types in the Jean Lafitte area is virtually identical to those found in the Jefferson-Orleans study area, use of these data was deemed appropriate.

Damage Evaluation. In determining the number of structures flooded and resulting impact, the Urban Flood Damage Program was utilized to correlate existing structural and hydrologic data. Within the program, nine different types of urban structures were evaluated using hydrologic profile data, structure locations, first floor elevations, depth-damage relationships, and structure and contents values to compute the depth of flooding and resulting damages for each structure for selected frequency flood events. Table 4 displays the number of structures by flood frequency for each flood damage reach.

Table 4
Total Number of Structures Flooded by Frequency a/

<u>Flood Frequency</u>	<u>Existing Conditions</u>	<u>6-Foot Levee</u>	<u>7-Foot Levee</u>	<u>8-Foot Levee</u>
1	4	2	2	2
2	91	14	14	14
5	232	39	39	39
10	243	110	110	110
25	279	253	158	146
50	295	295	273	232
100	304	304	304	304
200	305	305	305	305
500	305	305	305	305

a/ Total numbers are cumulative. Damages begin with yard and slab damage 0.5 foot below first-floor elevation.

Analysis of Automobile Damages. There are also damages to other properties in the flood plain, which are incurred as a result of urban flooding. Some of these, such as automobile damages, are directly related to the structural flood damages. The elevation of each automobile is determined by its corresponding structure elevation. Automobile damages are then calculated by correlating depth of flooding, depth-damage per automobile, and damage per automobile.

Automobile Valuation. The 1990 census indicated that there were 1.8 vehicles per household in Jefferson Parish. For automobile flood damage calculations, it was assumed that each residence had one automobile, which was susceptible to damage. For slab homes, automobiles were placed at 0.5 foot below the first floor level, assuming garages and carports are lower than first-floor elevations of homes. For pier homes, automobiles were placed at ground elevation. The application of only one vehicle per structure reflects that a number of vehicles may not be parked at home during the time of a flood due to other uses or that they may be evacuated. Therefore, they are not subject to flooding. The current average damage per automobile was estimated to be \$9,400, based on the replacement value of a depreciated used automobile according to the Louisiana Motor Vehicle Division and Census Data.

Summary of Expected Flood Damages To Structures, Contents, and Vehicles. The results of the flood damage analysis for existing and with-project conditions are presented in table 5 for structures and automobiles.

Table 5
Expected Annual Benefits to Structures and Automobiles

<u>Damage Category</u>	Without-Project	With-Project		
	<u>Existing Conditions</u>	<u>6-Foot Levee</u>	<u>7-Foot Levee</u>	<u>8-Foot Levee</u>
Residential	\$ 527,800	\$ 247,500	\$ 169,200	\$ 144,600
Commercial	261,000	111,100	82,000	75,800
Automobiles	436,800	154,500	116,500	99,200
Totals	1,225,600	513,100	367,700	319,600
Benefits		712,500	857,900	906,000

SECTION IV – INUNDATION REDUCTION BENEFITS FOR OTHER CATEGORIES

Introduction. A community typically incurs a variety of flood-related costs not associated with structural damages. These costs can be divided into three categories. The first includes the reduction in emergency costs, such as sandbagging and police overtime, repairs to public property, such as roads and bridges, and the subsequent clean-up of private and public properties. The second category includes the costs of evacuating and providing subsistence for those residents forced from their homes. The final category consists of the reoccupation costs required by homeowners in order to move back into their homes. Some of these damages and costs will be reduced due to the flood protection provided by the project. The reduction of these costs will be considered a benefit attributable to the project. This analysis is based only on existing condition and not future condition hydraulics. Thus, the benefits have been expressed as average annual values.

Emergency Costs. Benefits attributed to this category are defined as the elimination or lowering of emergency costs. The costs incurred as a result of flooding in the West Bank of Jefferson Parish were estimated for the following aspects of emergency operations: (1) Law Enforcement overtime (Sheriff's Office and City Police), (2) Department of Emergency Management overtime and food supplies for persons in the Emergency Operations Center, (3) Department of Public Works overtime for cleanup, placement of barricades, sand, sandbags, etc., and (4) Mosquito and Rodent Control Department overtime and supplies. The costs associated with evacuation and subsistence, and reoccupation are addressed in the following section of this report.

During October 1985, Hurricane Juan, after making one loop off the Louisiana coast and another loop on shore, eventually returned to the Gulf and made final landfall in the Florida Panhandle area. The storm affected Louisiana's weather for 4-5 days and the study area received widespread damages and incurred extensive emergency costs. Gages on the Harvey Canal indicated that the hurricane produced stages equivalent to a storm with an annual probability of .0167 (once in 60 years). The total emergency costs for the West Bank of Jefferson Parish for Hurricane Juan was estimated at approximately \$4 million. With a total of 2,500 structures flooded on the West Bank of Jefferson Parish, this would mean an average of \$1,600 of emergency costs per structure flooded above first floor elevation. After being price adjusted to November 1997 price levels, this amount was increased to \$2,239.

In order to determine average annual emergency costs, the emergency costs for storms of different frequencies of occurrence must be known. The number of structures flooded above first floor elevation for the 10, 50 and 100 storm events were provided by SID program outputs for the base and with-project conditions. These numbers were then multiplied by the \$2,239 average emergency cost per structure, in order to establish frequency-damage relationships. Finally, these relationships were entered into the Hydrologic Engineering Center's (HEC) Expected Annual Flood Damage Computation (EAD) program to determine the average annual costs for the project conditions.

Because fewer structures will flood with the project in place, a frequency-damage relationship with lower damages was entered into the EAD program. The portion of the average annual figure that will be reduced by the project is considered the emergency costs saved. Table 6 displays the associated cost savings.

Evacuation and Subsistence Costs. The emergency cost savings associated with the occurrence of hurricanes for both evacuation and subsistence may be claimed in this benefit category. The costs considered include meals, clothing and shelter assistance for evacuees. Hurricane Juan affected Louisiana's weather for four to five days as parishes along the Louisiana coast received widespread damages and incurred extensive emergency costs. Schools and armories were opened in the southern half of Louisiana for the evacuees forced to flee their homes because of flooding.

Based on May 1995 flood information, spending by non-profit organizations including the Salvation Army, the Volunteers of America, and the Southern Baptist Disaster Group, resulted in each family receiving \$370 in subsistence and evacuation compensation. Using the Engineering News Record to reflect November 1997 price levels, this amount was increased to \$399.

In order to determine average annual subsistence and evacuation costs, the subsistence and evacuation costs for storms of different frequencies of occurrence must be known. The number of structures flooded above first floor elevation for the 10, 50 and 100-year storm events were provided by SID program outputs for the base and with project conditions. These numbers were then multiplied by the \$399 total subsistence and evacuation cost per structure, in order to establish frequency damage relationships. Finally, these relationships were entered into the EAD program to determine the average annual costs for the project conditions.

Because fewer structures will flood with the project in place, a frequency damage relationship with lower damages was entered into the EAD program. The portion of the average annual figure that will be reduced by the project is considered the emergency costs saved. These reductions in emergency costs for the selected plan are shown in table 6.

Reoccupation Costs. Benefits attributed to this category are defined as the elimination or lowering of reoccupation costs. These costs result from the flooding of residential structures at or above first floor elevation, and include the many hours that homeowners spend to contract, supervise, and inspect repairs, to clean and disinfect their homes, and to fill out casualty loss forms for flood insurance and other disaster assistance. Interviews with former flood victims in the Amite River and Tributaries project area were used to determine the hours spent on the aforementioned tasks.

Based on discussions with the president of the Amite River Citizens Organization, the average time spent in flood clean-up per household was estimated to be 115 hours. Because the homeowners were forced to forego other activities, including work time, during the flood aftermath, an opportunity cost of \$14.59 per hour was assigned. This is the average hourly wage for the New Orleans MSA for employees covered under the Louisiana Employment Securities Law as of the third quarter of 1997. Thus, the total reoccupation costs for each household is $\$14.59 \times 115$ hours or \$1,678.

In order to determine average annual reoccupation costs, the reoccupation costs for storms of different frequencies of occurrence must be known. The \$1,678 cost per household was multiplied by the number of structures flooded above first floor elevation for events of three different frequencies of occurrence in the study area to develop a frequency-damage relationship. The frequency-damage relationship was entered into the EAD program to determine average annual reoccupation costs.

Because fewer structures will flood with the project in place, a frequency-damage relationship with lower damages was entered into the EAD program. The portion of the average annual figure that will be reduced by the project is considered the reoccupation costs saved. These reductions in reoccupation costs and emergency costs for the selected plans are shown in table 6.

Flood Insurance Administration (FIA) Cost Reduction Benefits. The net national cost of the flood insurance program includes the costs of claims adjustment, agent commissions, and the cost of servicing the policies. Potential benefits from a project will arise from a reduction in the administration overhead. This is achieved by any project which results in such property no longer being subject to flooding by a 100-year stage. The current administrative cost per policy is \$131.

In order to determine the magnitude of this benefit, all of the residential properties in the project were considered. The analysis began with the following conditions based on observation and experience as reported by Flood Insurance Administration (FIA) officials. The FIA indicates that the percentage of properties currently covered by flood insurance differs by flood zone and those proportions are: 100% for the 0 to 25-year zone; 80% for the 25 to 50-year zone; 60% for the 50 to 100-year zone; and none above the 100-year stage.

The structure files were sorted according to residential structures found in the 0 to 25, 25 to 50, and 50 to 100-year flood zones. Their total elevations were then adjusted for slope and compared to the with project 100-year stage and those which exceeded that stage were sorted listed and counted. The number of structures which were no longer subject to flooding by the 100-year stage with the project in place were then assumed to have no flood insurance in their flood zone. This number was then multiplied by the adjusted potential benefit for each flood zone and the sum of these benefits for each zone of each basin was then reported in table 6.

Total Emergency Costs. The total NED benefits for this category are determined by combining the average annual cost savings from emergency cost and damage to public property, evacuation and subsistence measures, FIA costs saved, and reoccupation of houses by flood victims. The total average annual cost savings, apportioned by the hydrologic reach, is shown in table 6.

Table 6
Total Average Annual Emergency Cost Savings

Emergency Cost Savings <u>Category</u>	6-Foot <u>Levee</u>	7-Foot <u>Levee</u>	8-Foot <u>Levee</u>
Emergency Cost Savings	\$ 137,300	\$ 143,700	\$ 145,300
Subsistence Cost Savings	28,000	29,300	29,600
Reoccupation Cost Savings	169,300	177,000	178,900
FIA Cost Savings	9,900	10,400	10,500
Totals	344,500	360,400	364,300

SECTION V – NET BENEFIT ANALYSIS

Average Annual Benefits. The economic justification of the plan given detailed consideration was determined by comparing estimates of the average annual costs and average annual benefits which are expected to accrue over the life of the project (50 years). Recommendation of any construction plan by the Corps of Engineers requires that average annual benefits equal or exceed average annual costs.

The values estimated for benefits and costs at the time of accrual were made comparable by conversion to an equivalent time basis using a designated interest rate. The interest rate used in this analysis is 7-1/8 percent. The period of analysis, or project life, utilized in the analysis is 50 years. The benefits and costs are expressed as the average annual value of the present worth of all expenditures and all plan outputs. These expenditures and outputs are measured at a specific point in time (base year). The base year, is the year in which the project becomes operational or when significant benefits start to accrue.

Estimated "with project" damages would be limited to the effects of rainfall or events exceeding the level of protection. The total benefits of the project include the benefits anticipated over the 50-year project. The benefits of the proposed plan were compared with the costs to determine the benefit-to-cost ratio as shown in table 7.

Average Annual Costs. Project costs developed include increasing the height of the existing levee and closure of any gaps in the alignment. Total project first costs also include costs for mitigation, real estate, and relocations. The schedule of yearly expenditures is annualized based on a base year of 2002.

Average Annual Net Benefits. The results of the final benefit-cost analysis for the various plans in the Lafitte project are summarized in table 7. All alternatives studied show a positive benefit-cost ratio. The 7-foot levee alternative shows the greatest net benefits which is \$386,800.

Table 7
Benefit-Cost Summary

	<u>6-Foot Levee Height</u>	<u>7-Foot Levee Height</u>	<u>8-Foot Levee Height</u>
Construction Costs	\$4,534,000	\$4,845,000	\$5,536,500
Real Estate	3,196,000	3,196,000	3,711,000
Relocations	693,200	693,200	767,000
Mitigation	19,000	19,000	22,500
Engineering & Design	412,100	412,100	412,100
Supervision & Administration	803,000	803,000	803,000
Interest During Construction	1,055,800	1,070,000	1,209,700
 Total First Costs	 10,713,100	 11,038,300	 12,461,800
 Average Annual Costs	 788,600	 812,500	 917,300
Operation and Maintenance	19,000	19,000	19,900
 Total Average Annual Costs	 807,600	 831,500	 936,300
 Average Annual Benefits			
Inundation Reduction	712,400	857,900	906,100
Emergency Costs Saved	137,300	143,700	145,300
Evacuation & Subsistence			
Costs Saved	28,000	29,300	29,600
Reoccupation Costs Saved	169,300	177,000	178,900
FIA Costs Saved	9,900	10,400	10,500
 Total Average Annual Benefits	 1,056,900	 1,218,300	 1,270,400
 Benefit-Cost Ratio	 1.3	 1.5	 1.4
 Net Benefits	 249,300	 386,800	 334,100

SECTION VI – NON-STRUCTURAL ANALYSIS

Non-structural measures are all those which reduce or avoid flood damages without significantly altering either the nature or the extent of flooding. Such measures reduce flood losses by either (1) changing the use made of floodplains (e.g., from residential to recreational use), or (2) retaining existing flood plain use with some accommodation of the flood hazard (e.g., elevating a resident). Non-structural measures include, but are not limited to, such actions as floodproofing of structures, regulation of floodplain use, temporary evacuation of hazard areas, relocation of activities to non-floodplain sites, acquisition of land or easements, redevelopment in a manner compatible with the flood hazard, and flood forecasting and warning.

Basically, two types of non-structural measures for flood protection exist – those that reduce existing damages and those that reimburse for existing damages and reduce future damage potential. Only those non-structural measures that reduce damages were investigated to varying degrees in this study and include the following:

- a. Floodproofing by waterproofing of walls and openings in structures.
- b. Raising structures in place.
- c. Constructing walls or levees around structures.

The following results were obtained through the analysis of five of the alternatives mentioned above:

Flood Proofing Option

Number of structures considered	213
First Costs	\$4,474,700
Average Annual Costs	329,500
Average Annual Benefits	430,400
Benefit-Cost Ratio	1.3
Net Benefits	100,900

Structure Raising Option

Number of structures considered	267
First Costs	\$6,039,800
Average Annual Costs	444,700
Average Annual Benefits	293,000
Benefit-Cost Ratio	0.7
Net Benefits	(151,700)

Small Walls Option

Number of structures considered	180
First Costs	\$3,286,600
Average Annual Costs	242,000
Average Annual Benefits	240,800
Benefit-Cost Ratio	1.0
Net Benefits	(1,200)

The non-structural portion of the Urban Flood Damage Analysis Program calculates the cost of implementing each alternative on a structure-by-structure basis using per square foot cost estimates specific to the type of alternative. Per square foot costs that were initialized at the time the program was finalized in 1988 were updated to February 1998 price levels using the Engineering News Record construction cost factors. Residential structures are evaluated using estimates of structure size, designated by small (S), medium (M), or large (L). Data input specific to non-residential structures includes the structure size (in square feet), number of doors, number of windows, height of windows from the ground, and number of 6-foot vehicular doors (e.g., garage doors). These data are used within the program to estimate the cost of implementing each non-structural measure considered.

The non-structural analysis concludes that the flood proofing option would be the only option that would be economically justified. Since the plan is not considered to be the NED plan, no further consideration was given to non-structural measures.

SECTION VII – RISK-BASED ANALYSIS

General. Even though every attempt is made to ensure accuracy, a degree of uncertainty is implicit in many areas of planning for water resource projects. The uncertainty arises due to error in the data being measured or errors inherent in the methods used to estimate the values of certain critical variables. The potential for error exists throughout the traditional analysis because each of the variables has been assigned a single point value rather than a range of values. In order to compensate for possible error, risk-based analysis can be applied to the planning and design of water resource projects. This approach, which quantifies the extent of systematic risk, provides the decision-maker with a broader range of information. Thus, a decision can be made that reflects the explicit tradeoff between risks and costs.

Overview of Risk-Based Analysis. Risk-based analysis was used to determine the NED levee height for hurricane protection. Also, the inherent uncertainty associated with each of the key hydrologic/hydraulic and economic variables in the analysis was quantified.

The analysis considered a range of possible values, with a maximum and a minimum value, for each economic variable used to calculate the elevation- or stage-damage curves, and for each hydrologic/hydraulic variable used to calculate the stage-frequency curves. It also considered a probability distribution for the likely occurrence of any given outcome within the specified range. The @Risk program used Monte Carlo simulation to derive the possible occurrences of each variable. Randomly generated numbers were used to simulate the occurrences of selected variables from within the established ranges and distributions. In a normal distribution, 68 percent of the possible outcomes occur within one standard deviation on either side of the mean (expected value), 95 percent occur within two standard deviations on either side of the mean, and 99.7 percent occur within three standard deviations.

For each variable, the computerized Latin Hypercube sampling technique was used to sample from within the range of possible values. With each sample, or iteration, a different value was selected. The number of iterations performed affects the simulation execution time and the quality and accuracy of the results. In the project-sizing template spreadsheet that selects from all the economic and hydrologic/hydraulic variables, 5,000 iterations were run. The sum of all sampled values divided by the number of samples yielded the expected value, or mean. This process was conducted simultaneously for each economic variable associated with each

structure inventoried. The resulting mean value and probability distributions formed a comprehensive picture of all possible outcomes. In order to illustrate the sensitivity of the results to changes in the number of iterations, New Orleans District conducted a test run of the economic uncertainty spreadsheets. It was determined that as the number of iterations was increased past 100, there was less than a 1 percent change in the mean or expected value. Also, there was considerably less than a 1 percent difference in the mean or expected value as the number of iterations was increased from 500 to 5,000.

Three @Risk simulation spreadsheets were used in the risk-based analysis for the Lafitte hurricane protection study. The first spreadsheet, which was developed in cooperation with Vicksburg District and Division, was used to calculate structural elevation-damage (or stage-damage) relationships in the risk-based analysis framework. The second spreadsheet, known as the project-sizing template, was developed by Hydrologic Engineering Center (HEC) and recently adapted for use in the Lafitte study by the Institute for Water Resources (IWR). This spreadsheet was used to integrate the results of the economic uncertainty analysis (elevation-damage curve with error) with the results of the hydrologic/hydraulic uncertainty analysis (stage-frequency curve with error) to produce expected annual damages under each of the three levee heights. The third spreadsheet was used to compare the without-project damages to the with-project damages, in order to produce the benefits under each of the three levee heights, and to perform the basic NED analysis.

Economic Uncertainty. In the Lafitte hurricane protection study, risk-based analysis was performed on four (4) key economic variables: structure values, contents-to-structure value ratios, first floor elevations, and depth-damage relationships. Each of these variables was analyzed for its impact on the elevation-damage curve. It should be noted that the additional benefit categories associated with structural inundation reduction benefits were not evaluated using risk-based analysis in the development of the elevation-damage curve.

Structure & Automobile Values. A sample of 18 residential structures was compiled during a field survey and valued using the Marshall and Swift (M&S) valuation Service. These values were then compared to the M&S value based on the more precise information provided by the owners of the 18 properties in order to determine the economic uncertainty associated with the field survey values. A similar procedure was used to compare the surveyed values of 28 non-residential structures with the M&S value based on information provided by the business

owner. The estimation error from conducting a field survey reflects possible miscalculations in the square footage of the structure, and/or inaccurate judgments regarding the age and quality of the structure. On average, the field surveyed values were 1.7% below the values obtained from more accurate homeowner assessment and 3.8% about the values obtained from the business owners.

A NORMAL probability density function was used along with the surveyed value and a standard deviation of 11.4% for residential structures and 11.6% for non-residential structures. For automobiles, a triangular probability distribution function was used with the average value of a used car of \$9,400. The average value of new car less taxes, license, and shipping charges was used as the maximum \$16,800, while the 10-year depreciation value of an automobile was used as the minimum value \$2,000.

Contents-to-Structure Value Ratios. Residential and commercial content information developed from on-site interviews with homeowners and business operators were used to develop contents-to-structure value ratios (CSVVR). These data were grouped for each content category, and a normal probability distribution was used to describe the uncertainty associated with the use of the CSVVR estimated from the interviews. The mean and standard deviation percentage derived for the residential categories are as follows: 71% and 24% for one-story residential structures; 50% and 30% for two-story residential structures; and 148% and 69% for mobile homes. The mean and standard deviation percentage for the 8 commercial categories are the following: 428% and 703% for eating establishments; 128% and 98% for grocery establishments; 23% and 13% for multi-family apartments; 78% and 79% for professional office-buildings; 82% and 108% for public facilities; 251% and 215% for repair structures; 148% and 117% for retail structures; and 372% and 540% for warehouse structures.

First Floor Elevations. The first floor elevations of structures were determined by using aerial photographs with 1-foot contours for the ground elevation and hand-levels in a vehicle during the field survey. This method was compared to determining the first floor elevation of 89 randomly selected structures throughout the Jefferson Parish area using engineering surveys. On average, the field survey method was .4 above the engineering surveys with a standard deviation of 0.6 feet. A TNORMAL probability density function was used to describe the

uncertainty associated with this variable because it was assumed that the errors would be randomly distributed within the truncated range of 1.2 feet.

Depth-Damage Relationships. An expert panel estimated a minimum, maximum, and most likely value for the damage percentage associated with each depth of flooding. A triangular probability distribution was used to describe the uncertainty associated with the use of depth-damage estimates made by the expert panel.

Economic Uncertainty Results. As discussed above, risk-based analysis was performed on 4 key economic variables: structure values, CSVs, first floor elevations, and depth-damage relationships. Each of these variables was analyzed for its impact on the elevation-damage relationships.

In order to develop an interior frequency-damage relationship, a damage with error relationship was developed for each stage associated with the frequency events for the without- and with-project conditions. Within the @Risk program, 500 iterations from the Latin Hypercube sampling were run for each of the stages to determine a mean (expected value) damage and a standard deviation of the error for the interior reach (within the existing levee system). Each iteration uses a randomly selected value for each of the four economic variables. As the results of each iteration were compiled for an elevation, an elevation-damage with error curve was developed for the stages associated with the frequency events.

Table 8 shows the economic uncertainty surrounding the elevation-damage relationships associated with the stages for the various frequency events.

An exterior stage-frequency curve (outside the existing levee system) was also provided by the H&H Branch. This curve includes stages for nine frequency storms (1, 2, 5, 10, 25, 50, 100, 200, and 500-year events). A direct relationship between the exterior stage and the interior damage was assumed (i.e., an exterior stage of 6.0 feet results in a given interior damage value regardless of the event frequency). Combining the exterior stage-frequency relationships with the corresponding interior frequency-damage relationships derived an exterior elevation/interior damage relationship with error. These relationships were developed for the without-project conditions, and for the three levee sizes (6-foot, 7-foot, and 8-foot levee heights). These

curves, which take into account the economic uncertainty, were then put into the project-sizing template that also addresses the inherent hydrologic/hydraulic uncertainty.

Hydrologic/Hydraulic Uncertainty. Risk and uncertainty analysis was performed on the exterior stage-frequency curves provided by the H&H Branch. The computer program "LIMIT", which was developed by HEC for non-analytical frequency curves, was used in the computation of confidence limits for each stage. The program extrapolated the stage-frequency curves for the 99.9 percent chance of exceedance (1-year storm) to the 0.01 percent chance of exceedance (10,000-year storm). The confidence level was found to be higher for the more frequent storm events, and lower for the less frequent storm events. For example, the computed error increases from 0.063 feet at the 50 percent chance of exceedance to 1.308 feet at the 0.01 percent chance of exceedance. (See the Hydrologic/Hydraulic Appendix for a more complete discussion of this type of uncertainty).

Project-Sizing Damage Results. The second spreadsheet used in the risk-based analysis was the project-sizing template that was developed by HEC and recently modified by IWR for stage-frequency data. It was used to integrate the results of the economic uncertainty analysis (elevation-damage with error) with the results of the hydrologic/hydraulic uncertainty analysis (stage-frequency with error) to produce the without-project and with-project expected annual damages in a risk-based framework. Within the @Risk program, 2,000 iterations from the Latin Hypercube sampling were run for the without-project conditions, and for each of the three levee sizes. This process was used to determine a mean (expected value) damage and a standard deviation of the error. With each sample, or iteration, a different flood event was selected from the range of possible events. The sum of all sampled values divided by the number of samples yielded the expected value, or mean damage with error, which together with the probability distributions formed a comprehensive picture of all possible outcomes. Table 9 shows the mean or expected damage, standard deviation of the error, and the minimum and maximum damage values for without-project conditions, and for the three levee sizes.

Project-Sizing Expected Annual Benefit Results. Project benefits with error are defined as the difference between the without-project and with-project damages with error. In order to calculate these benefits with a mean, or expected value, and a probability distribution, a third @Risk spreadsheet was developed using the histogram function from the statistical reports produced by the project-sizing template. The histogram function contains the range of

damages and their associated probabilities for the without-project and with-project conditions. Within this @Risk spreadsheet, 5,000 iterations from the Latin Hypercube sampling were run for the without-project conditions and for each of the three levee heights under the with-project conditions. This procedure was used to determine a mean (expected value) benefit and a standard deviation of the error. With each sample, or iteration, a different level of damage was selected from the range of possible without-project and with-project damages. Since there is a correlation between the without-project and with-project conditions, a correlation factor was used in the program to ensure that with each iteration, the without-project and with-project damages selected from the range would have a similar set of underlying assumptions. For example, if the program under without-project conditions randomly selected a structure value below the mean within the probability distribution, then the program would also randomly select a structure value below the mean under with-project conditions. Thus, if a value representing low without-project damages were selected, a similar low with-project damage value would be selected from the probability distribution. The sum of all sampled values divided by the number of samples yielded the expected values, or mean without-project damages and mean with-project damages. Finally, the program took the difference between the mean without-project damages and the mean with-project damages and produced the mean expected annual benefits and probability distribution for each of the three levee heights.

Table 10 shows the expected benefits, standard deviation of the error, and the minimum and maximum benefit values for the with-project conditions under the three levee alternatives. It also illustrates the effectiveness of each levee size in reducing the without-project expected annual damages.

Comparison of Project-Sizing Expected Annual Benefits and Costs. The expected annual benefits with error for each of the three levels of protection were then compared to the average annual costs for the three levee heights, which was derived from the traditional non-risk based analysis. Table 7 of this appendix provides a detailed summary of the average annual costs for each of the three levee sizes, including interest during construction, gross investment, operation and maintenance costs, and mitigation costs.

Table 11 shows the first costs, the average annual costs, expected annual benefits from the project-sizing template, the net benefits derived for each of the three levee heights, and the benefit-cost ratios. The project-sizing average annual benefits are approximately 7 to 8 percent

lower than those derived using the traditional analysis. However, a consistent relationship exists between the benefits and the three levee heights under both the traditional and risk-based approaches. In spite of being reduced, the project-sizing benefits remained considerably higher than the costs of the 3 levee sizes.

The probabilities associated with a given level of net benefits can be determined by subtracting the mean expected annual benefits from the annual cost under the 3 levee sizes. The expected annual net benefit probability curve was adjusted to include the point estimates for the additional benefit categories associated with structural inundation reduction benefits before being converted to a net benefit probability curve. Figures 1, 2, and 3 display the project-sizing net benefits for each of the levee sizes and the corresponding probabilities derived from the risk-based analysis. As shown in the figures, there is better than a 99 percent chance that net benefits will be positive and the benefit-cost ratio is greater than 1.0 for a 6-foot levee, 99.1 percent for a 7-foot levee, and a 97.9 percent for an 8-foot levee.

NED Level of Protection. The NED level of protection is the one that most reasonably maximizes net tangible economic development benefits consistent with Federal regulations. Benefits are maximized at the point where the excess benefits over costs is the greatest. The net benefits of the project begin to decrease at any level of protection past this point. The NED level of protection was determined by comparing the average annual costs to the mean expected annual benefits with error under each of the three levee heights.

As previously shown in Table 11, the 7-foot levee height level of protection yielded the highest net benefits and is the NED plan. It should be noted that this alternative was also found to yield the highest net benefits in the traditional analysis. As shown previously in Figure 2, which displays the expected annual net benefit-probability curve for the 7-foot levee height, there is a 99.1 percent chance that net benefits are positive and the benefit-cost ratio greater than 1.0.

Table 12 summarizes the annual net benefits for each plan considered. In addition, the table presents an estimate of net benefits that exceed specified probabilities. In the case of the NED plan, i.e., the 7-foot levee alternative, there is a 95 percent probability that annual net benefits will exceed \$247,000. The table also suggests that the probability that annual net benefits for the NED plan will exceed its expected value (\$533,000) is approximately 48 percent.

If construction alternatives other than the NED plan are to be recommended, table 12 provides useful information that may assist in a decision. For instance, while the 6-foot levee plan would be less costly to implement compared to the 7-foot levee plan, the probability that net benefits for the 6-foot plan will be less than \$533,000 (the expected value of net benefits for the 7-foot levee plan) is 86 percent. If, however, the 8-foot levee is selected, there is a 42 percent probability that net benefits will be as high as \$533,000, the expected value of net benefits associated with the NED plan.

In the evaluation of these results as an aide to plan selection, explicit recognition must be taken of the degree to which project sponsors are averse to or accepting of risk-taking behavior. In the example provided above, the selection of the 8-foot levee plan may be viewed as a risky decision since the expected value of net benefits is less than that of the NED plan; however, the potential rewards for this risky behavior may also be seen as sufficient to justify this decision.

Table 8
Stage-Damage Relationships*
(\$1,000's)

<u>Elevation</u>	<u>Expected Damages</u>	<u>Standard Deviation</u>
1.8	\$ 31.2	\$ 30.0
2.0	57.6	33.1
2.1	77.2	40.7
2.5	221.2	85.3
2.7	349.2	117.3
2.9	527.0	154.7
3.2	905.3	217.7
3.4	1,242.1	264.6
3.7	1,881.1	339.1
3.8	2,129.2	365.3
4.0	2,673.3	420.5
4.1	2,967.5	447.9
4.6	4,592.8	564.3
5.0	5,965.0	639.8
6.0	8,986.4	764.4
7.0	11,148.6	850.3
7.3	11,672.4	867.7
8.0	12,686.3	890.3
9.0	13,666.1	895.5

*500 iterations, latin Hypercube sampling.

Table 9
Expected Annual Damages With Error
Without and With-Project Conditions
(\$1,000's)

		<u>With Project</u>		
	<u>Without-Project</u>	<u>6-Foot Levee</u>	<u>7-Foot Levee</u>	<u>8-Foot Levee</u>
Expected Damages	\$1,205	\$ 570	\$ 432	\$ 383
Standard Deviation	381	265	206	185
Minimum Damages	222	35	35	35
Maximum Damages	2,816	1,786	1,419	1,271

Table 10
Expected Annual Benefits With Error
(\$1,000's)

	<u>Project Alternatives</u>		
	<u>6-Foot Levee</u>	<u>7-Foot Levee</u>	<u>8-Foot Levee</u>
Expected Benefits	\$ 635	\$ 773	\$ 822
Standard Deviation	118	176	198
Minimum Benefits	186	187	187
Maximum Benefits	1,030	1,389	1,545
% Damages Prevented	53%	64%	68%

Note: Table 9 and 10 do not include the additional benefit categories associated with inundation reduction to structures including emergency and FIA cost reductions.

Table 11
Summary of Expected Annual Costs and Benefits
(\$1,000's)

Construction <u>Plans</u>	First <u>Costs</u>	Expected Annual <u>Benefits 1/</u> <u>Costs 2/</u>		Net <u>Benefits</u>	B/C <u>Ratio</u>
6.0 feet	\$3,372	\$ 979	\$581	\$ 398	1.69
7.0 feet	3,573	1,133	600	533	1.89
8.0 feet	4,084	1,186	684	502	1.73

1/ Benefits were computed using risk-based analysis for inundation reduction to structures and vehicles and the point estimates from the other associated benefit categories were added.

2/ Costs were calculated using non-risk-based analysis.

Table 12
Expected Value and Probabilistic Values of Net Benefits
(\$1,000's)

Levee <u>Alternative</u>	Expected Annual NED <u>Benefit and NED Cost</u>			Probability Net Benefits Exceeds <u>Indicated Amount</u>				
	<u>Benefits</u>	<u>Costs</u>	Net <u>Benefits</u>	<u>0.95</u>	<u>0.75</u>	<u>0.50</u>	<u>0.25</u>	<u>0.05</u>
6-Foot \$562	\$ 979	\$581	\$398	\$204	\$313	\$388	\$491	
7-Foot 815	1,133	600	533	247	417	508	660	
8-Foot 825	1,186	684	502	181	374	469	638	